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A review of the environmental factors influencing calf respiratory disease

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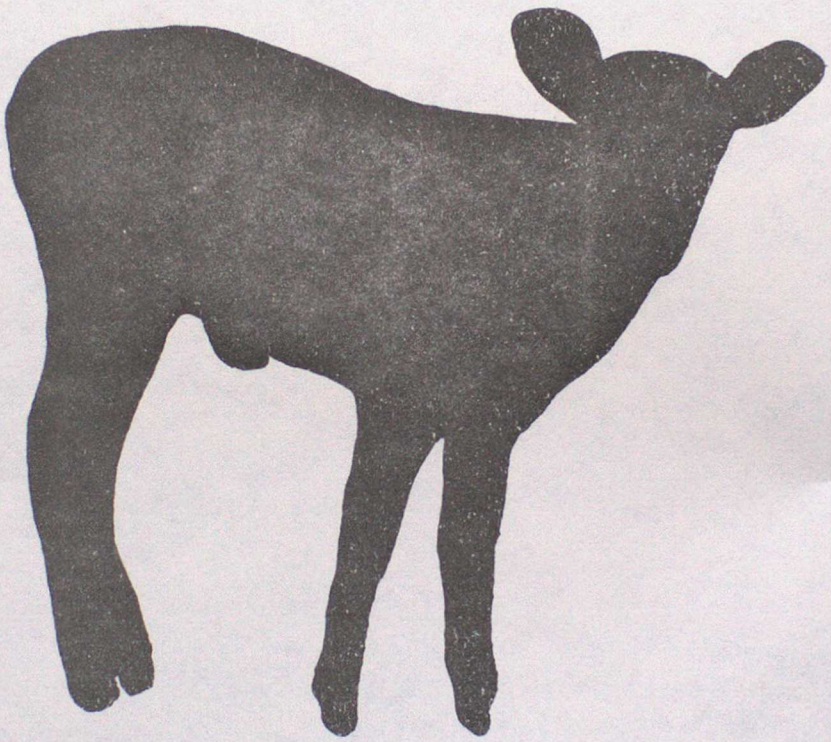

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1. Introduction

Respiratory disease is a major problem for calf rearers in the UK especially since the introduction of intensive systems of rearing. Producers lose over £10 million (1) a year through pneumonia in housed calves as a result of deaths, culling and depressed growth rate although it is widely acknowledged that much of this loss could be avoided by paying careful attention to timely veterinary treatment, better housing and careful stock control. These factors will be discussed in more detail shortly.

The disease was first studied during the 1940's, and it was evident from work by Phillip and Darbyshire (2) that bacteria*, viruses* and other infectious agents play an important role during the infection of an animal. Recent work has shown that the microbiology* is extremely complex and it seems likely that infection is the result of one or more viruses interacting and gaining a 'hold' on a stressed animal; the importance of mycoplasmas*, however, has lately been realised after the isolation of several new mycoplasmas from infected animals. PI3 virus, adenovirus and reovirus are considered to be the most important viral agents associated with pneumonia in calves in Great Britain. The infection by viral agents is often followed by a secondary bacterial infection (usually Pasteurella haemolytica or Corynebacterium pyogenes) and the severity of the mortality of an outbreak may be associated with the degree of secondary bacterial invasion that has occurred.

Virus pneumonia is widespread throughout the country and most cattle will encounter it at some time; it is especially common in animals between 8-16 weeks of age although it can occur at any age if conditions are favourable. An outbreak on a large rearing unit can have very serious financial consequences which suggests that the cost of providing good housing and management will easily be repaid through increased outputs of animals.

Calves are most likely to succumb to infection when stressed or when challenged by a large pathogen* population. The importance of good housing and management in preventing disease outbreaks are considered in the following sections.

2. Housing

One of the main reasons for housing livestock comes from the knowledge that by protecting animals from extremes of climate productivity and reproductive efficiency can be increased (3). There are, of course, management reasons for undertaking housing (not necessarily related to the 'thermal comfort' of the animal) concerned with making routine tasks easier (eg handling and feeding) and protecting the land (eg avoidance of poaching).

Smith (4) equated the value of housing in terms of food saving through avoidance of coldstress and attendant weight loss. He concluded that over a winter season of November through to March (162 days) the equivalent of a house providing a 1°C lift over the external ambient air temperature is provided by the additional feeding of 16.2 kg barley (0.3 cwt) or of 24.3 kg hay (0.45 cwt) for a 200 kg animal (0.6 cwt barley and 0.9 cwt hay respectively for a house providing a 2°C life). In practice however, the temperature lift within the house is liable to be much greater than 1 or 2°C so that food savings are likely to be significantly higher than those mentioned.

2.1 Types of House

The type of housing used for calf rearing varies from the controlled-environment house down to a temporary structure of straw bales and depends upon the system of rearing. The economic benefits of using the former for the intensive production of veal calves has proved under commercial conditions to justify the cost, but where maximum growth rate is not required the economic gains are unlikely to make such a house a viable proposition.

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*All asterisked words in this paper are given a full definition in the glossary

The controlled environment house, however, appears to be a misnomer as often only temperature is controlled (although in practice thermostats are often wrongly set or fans are inadequate so that even the temperature is poorly controlled) so that 'temperature controlled' house would be more appropriate. Usually these houses are fan ventilated with supplementary heating as opposed to the so-called 'climatic" house which is naturally ventilated by the 'stack effect' and attempts to simulate aspects of the environment of the outwintered, suckled calf by providing shelter from the weather and direct air currents without any limitation on air volume created by a building. The climatic houses may be temporary or permanent and often depend upon the calf to control its own micro-environment.

2.2 Insulation and Ventilation

For the construction of specialised calf houses (rather than the often ad-hoc modification of existing buildings which may prove unsatisfactory), the two main factors to be considered are good insulation and adequate ventilation. Good insulation is vital if extreme temperature fluctuations are to be avoided in winter whilst also keeping temperatures down in summer. Modern houses tend to be wooden framed with little thermal capacity in contrast to the old stone buildings which moderate the climate most efficiently; however the expense of stone structures is prohibitive. The provision of good insulation allows the use of lower ventilation rates, without the consequent condensation, which in turn reduces heat loss to the ventilating airstream.

A good air flow (0.37-1.87 $m^3/h/kg$ liveweight) through a building is required to keep temperatures and humidities down to reasonable levels as well as preventing a 'build-up' of gases (eg ammonia) and micro-organisms* in stagnant pockets of air. Smith (5) looked at the role of site in determining the ventilation characteristics in the naturally ventilated house. He considered three farms with differing animal performance (as indicated by the incidence of respiratory disease and the rate of liveweight gain) and found that good animal performance occurred in the house situated close to the brow of a hill. Of the two remaining houses, one was buried within a complex of older farm buildings and the other well separated from other buildings but situated in a natural hollow with rising ground on three sides; in these two houses animal performance was poorer than in the unit located on a hill Smith concludes by saying:" as a general principle one might suggest that beef units do not need topographic or local shelter; they should be sited to obtain maximum air movement through them in the critical, light wind situations, where removal of the heat and moisture loads placed on the building air by the animals may be primarily by stack effect". Furthermore, ventilation due to the stack effect is a function of stock density in addition to the resistance to air flow imposed by inlet and outlet design and separation.

Ventilation rate should not be sacrificed to maintain calf house tempe rature as a 'build-up' of infection may well result with a much greater economic loss occurring than would be caused by lower temperatures. A survey of calf mortality in relation to calf house design in the UK (19) showed that in 15 farms with low mortality (<2%), most buildings had permanently open ventilators in contrast to 14 high mortality farms where this was not the case. Furthermore, a survey by McFarlane (1966) of 10 beef buildings found lowest mortality in houses with little temperature lift (over the outside) and in which relative humidity approached outside conditions with good air-flow.

3. Management

Careful management is essential if costly disease outbreaks are to be avoided. Frequently the wrong enterprise is chosen for the existing buildings, labour and capital available or a new enterprise is constructed without obtaining expert advice on the choice and siting of buildings etc. Factors under the farmer's control include:

i. choice of calf

ii. building type and construction details

iii. ventilation system

iv. floor space per calf and bedding

v. air space per calf

vi. penning regime

vii. feeding regime

viii. animal behaviour

ix. environment within the house

x. disinfection regime

Points (ii) and (iii) have already been covered, the others will be discussed now.

3.1 Choice of calf

The selection of the most suitable breed of calf for rearing for beef production depends on the system to be used. In starting an enterprise it is worth remembering that the susceptibility of calves to infection differs according to breed: Ayrshire calves for example were found to be more resistant to infection than Friesian and Jersey calves (7) and may be associated with the better insulation arising from the thicker skins of Ayrshires. This factor, of course, must be weighed up against the sale value of the carcass to determine the most profitable course of action.

Ideally, the rearing of calves should take place on their 'parent' farm. The majority of farms today, however, tend to buy-in stock from a number of sources (usually auction markets). The higher mortality of bought-in calves has been contributed to the 'stress' upon the animals resulting from the use of such markets which necessarily involves the gathering together of calves from various sources, and their transportation. It is believed that stressed animals are more prone to infection (the so-called 'transit' fever and 'shipping fever' in the USA). Hardy (8) showed that weight at purchase of market-bought calves was negatively correlated with subsequent mortality to three months . Farmers should ensure from dealers that the animals have received adequate colostrum from their dams. As most cattle will have come into contact with pneumonia viruses at some stage of their lives, many cows will have developed protective antibodies which can be passed to the calves, offering them 'passive immunity' for a short time. It is thought that this initial protection allows an animal to support a gradual and controlled establishment of pneumonic pathogens, during which time the immune system can develop adequate levels of specific antibodies, rather than be overwhelmed by a sudden influx of large numbers of pathogens (7).

3.2 Floor space per calf and bedding

It is essential that all cattle, whether tethered or in pens, should have sufficient room to be able to groom themselves without difficulty and to be able to lie down freely; the width of the pen for a singly penned animal therefore should not be less than the height of the animals' shoulder. Damp floors lead to chilling and a properly insulated drained floor (eg. slatted floor) is a necessity if discomfort is to be avoided.

3.3 Air space per calf

Sufficient air space per animal acts as a buffer against inadequate ventilation. Air space should be related to ventilation rate and values of 5.0-7.0 m^3 per calf have been recommended; Thompson (10) found a lower mortality rate in calves with greater than 7.36 m^3/calf.

3.4 Penning regime

Where calves are artificially reared from soon after birth, some form of calf pen is required. There is a great diversity of opinion as to whether calves should be reared in individual pens, in groups of 3-4 or even in much larger groups of perhaps 15-20. It has proved beneficial to keep calves in individual pens until they are at least one month old (3 months if maximum weight gains are required) as this prevents the animals from sucking each other, reduces the likelihood of cross-infection and provides less competition for food whilst allowing easier control of individual diets. Grouping the animals together, on the other hand, allows the animals to keep warm and avoid draughts by huddling together.

Draughts can have a spectacular effect on individually penned calves, pneumonia developing only in calves in the draught. Solid sided pen partitions can be used to prevent draughts so long as adequate air flow patterns can be maintained. It is also very important to have lids on the back of the pens to offer some individual protection for the calves, particularly when low speed cold air enters the building through inlets directly above the calves.

3.5 Feeding regime

The nutritional requirements of the calf have been reviewed by Roy (11) and will not be considered here.

The age of weaning* appears to be particularly important in predisposing calves to pneumonia and may be associated with the lower intakes of productive energy, lower fat deposition and thinner-skins of early weaned calves. Quarmby (12) suggested that early weaning may be stressful and showed that under range conditions in the USA, the first clinical signs of pneumonia appear shortly after weaning, at which time calves are on a low plane of nutrition (13). More recent work (14, 15) has shown that weaning at 5 weeks old increases susceptibility to respiratory infections and consequently reduces performance up to 6 months of age in contrast to weaning at 12 weeks or later.

Smith (4) looked at the consequences of cold stress on young beef cattle in the average winter in Eastern England. He concluded that in cold stress situations there are physical advantages in rations of low energy concentrations compared with rations of high energy concentrations. Stobo and Roy (14) mention that the feeding of high concentration milk substitute diets during veal production appeared to predispose the animals to disease.

3.6 Animal behaviour

The dispersion of animals within a building reflects their environmental preferences. Jericho (17) mentions the importance of cattle being able to select their own environment in reducing the incidence of respiratory disease; the extent to which individually penned animals within a house are allowed a preference, however, is likely to be small. The behaviour patterns in response to high and low temperatures were reviewed by Baldwin (18). In high ambient temperatures, for example, their behaviour is characterised by reduced food intake, increased water intake seeking shaded areas; the animals also tend to avoid each other, lie down and spread saliva over the body to aid cooling.

Hafnez and Lineweaven (19) found that if a calf's need to suck is not satisfied during feeding then non-nutritional sucking of walls and other calves occurs, and thus increases the chances of cross-infection; this is one factor favouring nipple feeding over bucket feeding.

3.7 Disinfection

When large numbers of calves are passed through a calf house, there is a gradual 'build-up' of subclinical infection from bacteria and viruses. To prevent such a 'build-up', there should be a sterilisation break (about 6 weeks) between batches of calves during which time the houses are thoroughly disinfected. If a sterilisation break is impractical because calves are being introduced into the calf house in succession as they are born, cleaning and disinfection of individual pens should be carried out as soon as they are vacated. All transport vehicles, market premises and equipment should also be treated. Sick animals are a source of infection and should be isolated from the stock as soon as possible, and their pens disinfected.

4. Environmental Factors associated with the weather

"It is generally acknowledged in practice that the incidence and severity of enteric and respiratory diseases in cattle are influenced by environmental stresses, particularly those associated with the weather" (20). Harkness (21) reviewed the role of the environment in enzootic pneumonia and suggested that the climate and the air hygiene within the calf house may be important factors although the relative importance of such factors as air temperature, air movement, relative humidity, ammonia concentration etc. have not yet been elucidated. Miller et al (22), however, failed to find any correlation between weather data (air temperature, vapour pressure, soil temperature, grass temperature, hours of sunlight and rainfall) and calf mortality although weekly average values of these parameters were used, which may not have been sensitive enough to detect short term effects.

The following paragraphs deal with the specific environmental associations with the disease.

4.1 Season

The incidence of pneumonia in housed calves in the UK is higher in winter than summer and does not generally affect animals younger than 1 month of age (illustrating the benefits of adequate colostrum). Detailed analyses of records from individual units show either an increased incidence during the period September to March (23, 15) or that peaks of disease occur in late autumn and early spring, with a slight decline in mid-winter (24, 25). The former pattern suggests a progressive 'build-up' of infection in a building throughout the winter while the latter suggests, perhaps, that the more changeable weather conditions experienced during the spring and autumn predispose to disease more than does severe cold (20).

An analysis of the influence of meteorological factors on calf mortality rate (CMR) in Tulare County California (26) revealed that Peak death rates were in October-January and were correlated more closely with rainfall than with any other single weather factor. The authors conclude that CMR was associated with "cold, wet and windy conditions", although no absolute values for this definition are given.

Research (15) has shown that even with a very high air space per calf (20 m^3) and 24 changes of air per hour, high humidity at an environmental temperature of 14.5°C, or low humidity at an environmental temperature of 21°C, predisposed Jersey and Friesian calves to respiratory infections. These findings support the hypothesis that cold damp and, to a lesser extent, hot dry conditions seem to be detrimental.

4.2 Air temperature

The importance of air temperature in the aetiology* of pneumonia has been reported by several workers. Recent clinical studies by Wiseman et al (27) and Bryson et al (28)

have related the onset of clinical diseases to changes in weather conditions such as a drop in temperature while the histology* of the respiratory epithelium* of calves was influenced by the temperature and humidity of the inspired air (29). Mitchell (30), however, in a book on calf housing suggested that temperature is not an important factor.

The effect of air temperature on cattle is best quantified in terms of its effect on metabolic rate. Webster (20) mentions that cattle are very tolerant to both heat and cold and describes a wide range of temperature wherein the animal can maintain homeothermy* with negligible stress. Values for the lower critical temperature (ie the value below which cold starts to constitute a metabolic stress) are given in Table 1. It can be seen that the only cattle likely to be stressed by cold alone are very young calves or slightly older animals whose normal metabolic rate has been reduced by disease(31, 32) although the udder of dairy cows may be affected.

The main effect of air temperature appears to result from cool or slightly cool temperatures reducing the ability of the lungs and lower respiratory tract to remove micro-organisms from the lung. Phillip (33) concluded that the ciliated* and mucus-secreting cells of the respiratory tract (responsible for pathogen removal), appeared to be susceptible to environmental conditions.

Large diurnal variations in calf house temperature and relative humidity were considered to be more harmful than high values provided that these did not exceed the upper limit although these suggestions are based on experience rather than on experimentation (34) Work in Switzerland (34) found the optimum conditions for preventing respiratory infection in veal calves to be:

Environmental temperature: 18°C at beginning and 12°C at end of fattening period
Relative Humidity: 60-80 per cent
Maximum tolerable CO_2: 3500 parts per million (ppm)
Maximum tolerable NH_3: 25 ppm
Air movement: not to exceed 0.2 ms^{-1}, except during hot weather, when 0.3 ms^{-1} is acceptable

In the UK it is recommended that concentrations should not exceed 0.1% for CO_2 and 5-10 ppm for NH_3.

Smith (35) reports of two 'cold stress' days before an outbreak, such that the temperature fall, day max to night min was 1.5 times the mean monthly diurnal range and the min was ≤ 0°C. A study by Smith et al (36) on feline respiratory disease suggested that "if a suitable virus is present in the community, a serious infection is possible if two cold stresses are experienced separated by a period of time equal to the incubation* period". The temperature fall on these 'cold stress' days was found to be some 50 per cent greater than that on surrounding nights, on average.

4.3 Wind, rain and sun

The main effect of wind and rain on an animal is to increase its heat loss and thus the intensity of cold stress at any given air temperature (32). In Table 1, for example, an increased air movement from 0.2 to 2.0 ms^{-1} elevates the lower critical temperature of a young calf from 9°C to 17°C. Draughts of this kind (2.0 ms^{-1}) are common in calf houses (around doors, through inlets etc) and "chill" the animal sufficiently to produce a substantial increase in metabolic rate and perhaps a drop in resistance to infection. On the other hand, draughts tend to blow away micro-organisms within the house while rainfall tends to precipitate them. C D Mitchell (unpublished work) observed that there were no cases of respiratory disease in yearling cattle kept over winter in a topless, slatted-floor unit in Aberdeenshire, whereas about 15% of yearlings housed on the same premises required treatment.

This shows that provided the animals are not too exposed to the weather, the direct stress of the weather has little effect upon the animals and one should perhaps concentrate more on reducing the pathogen levels within the buildings.

It has been shown, however, that cold, wind and rain can predispose animals to indigestion, which may consequently lead to infection reinforcing the view of building specialists that animals should be protected from the direct 'blast' of the weather. Sunshine, though, reduces body heat loss and accelerates the death rate of pathogens.

4.4 Humidity

Water vapour arises not only from the animals themselves but also from floors, straw, water bowls etc. The removal of water vapour is governed by the water carrying capacity of the ventilating airstream and by the ventilation rate (ie air changes per hour) so that buildings with poor drainage and low ventilation rates inevitably have high relative humidities (RH's).

Donaldson (37) provided some interesting statistics on the effects of temperature and humidity on the death rate of pathogens and these are presented in Table 2. The figures indicate that both high and low humidities are detrimental. Death rates for E.coli and mycoplasma were greater at 70.0% RH than at higher or lower values while Rhinoviruses showed a gradually falling death rate as humidity increased. In contrast PI3 and IBR survived better at low humidities (which also dry the mucous membranes responsible for removing pathogens from the respiratory tract) indicating that infection is possible over a wide range of humidity. Experiments at Drayton and Mowthorpe EHFs (38,39) failed to show any marked effect of environmental temperature and humidity on the incidence of calf disease in calf houses with differing heating and ventilation systems. Beer et al (40) mention that there is a possibility that at very high RH there is accelerated sedimentation of airborne pathogens in large aerosols; this has its parallel in pig 'sweat boxes' in which it is claimed the number of airborne particles is reduced, as is the bacterial complement of the atmosphere (41).

High humidities do not chill cattle directly but instead restrict the evaporation of sweat from the coat causing the coat to become damp. A change of airstream, however, from warm humid air to cold dry air (as happens during the passage of a cold front) can result in a sudden drop in RH. The accumulated sweat will then be allowed to evaporate freely with the animal becoming severely chilled (20). In most well-ventilated buildings this is unlikely to happen except perhaps, when the ventilating airstream is almost saturated; it appears that in such buildings, respiratory infections stem from an increased challenge of the parasite rather than a reduction in the resilience of the host.

4.5 Climatic Change

The problem with weather in the UK is its variability. Webster (41) showed that cattle can adapt to a very wide range of environments so that ultimately they constitute little or no stress. The thermal stress is governed less by absolute values of weather but more by the extent to which they differ from the environment to which the animal is accustomed. Severe short-term weather fluctuations can reduce systemic resistance to infection by evoking the alarm phase of the General Adaptation Syndrome of Selye (42). After the adaption phase has been achieved, resistance returns almost completely to normal.

Environmental stresses on housed cattle are rather rare but, as already mentioned, young animals may be subject to a cold "chill." Cattle that are stressed by sudden cold, or heat, while in a house are faced by the double problem of intense challenge and lowered resistance simultaneously, which is one reason why pneumonia is much less of a problem in stock reared out of doors.

Although intuition tells us that sudden weather changes can affect the ability of

pathogens to colonise cattle for certain reasons, there is little evidence to back this up. The true effects of the microclimate on predisposing calves to respiratory disease are only likely to be elucidated after long term records of meteorological parameters in the vicinity of the calf can be related to records of outbreaks. This is obviously a field where much more work needs to be done.

Glossary of terms

Bacteria - microscopic unicellular plants of widely distributed class, especially of a kind which cause disease.

Viruses - any of numerous kinds of very simple organisms smaller than bacteria, mainly of nucleic acid in protein coat, existing only in living cells and able to cause diseases.

Microbiology - study of micro-organisms

Mycoplasma - an infective agent distinct from bacteria as well as from viruses. In size they resemble a large virus and they are filterable, but they can be cultivated on artificial media.

Pathogen - agent causing disease

Micro-organism - organism not visible to naked eye eg. bacterium or virus.

Wean - accustom a young animal to food other than milk.

Aetiology - science of the causes of disease

Histology - Science of organic tissues

Epithelium - tissue forming outer layer of body surface or lining of cavity that opens to body surface.

Homeothermy - maintenance of body heat

Cilium - hair like vibrating organ on animal and vegetable tissue

Incubation - phase through which germs of disease pass before development of first symptoms

Microclimate - climate of small area

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TABLE 1 Lower critical temperature of cattle housed in conditions of very low air movement (0.2 $m.s^{-1}$) and in a draught (2 $m.s.^{-1}$) (from Webster, 20)

	Body weight (kg)	Coat depth (cm)	Heat production ($W.m^{-2}$)	Thermal insulation ($K.m^2\ W^{-1}$) I_t	I_e*	Lower critical temperature (°C) **V = 0.2	V = 2.0
Cattle							
Newborn calf	35	1.2	100	0.09	0.25	+ 9	+ 17
1 month old	50	1.4	120	0.10	0.26	0	+ 9
Veal	100	1.2	154	0.25	0.25	- 14	- 1
Store cattle, maintenance	250	2.0	157	0.17	0.32	- 32	- 20
Beef cow, maintenance	450	2.9	107	0.22	0.36	- 17	- 9
Dairy cow, 22kg milk d^{-1}	500	1.2	154	0.20	0.25	- 26	- 13

* I_e measured in still air (0.2 $m.s^{-1}$) ** V = air velocity ($m.s^{-1}$)

TABLE 2 Some effects of temperature and relative humidity on death rate of pathogens

	Temperature (°C)	Relative humidity (%)		
		50	70	80
E. coli	Least at 15°	slow	rapid	slow
Mycoplasma	10 > 15°	slow	rapid	slow
Rhinovirus	Unaffected	decreases →		
PI3, IBR	Unaffected	increases →		